Structural Roof Appraisal

Coach Lane Campus,
Northumbria University

February 2024

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Document Validation

Revision History

Revision Ref	Issue Date	Purpose of issue / description of revision
01	07/02/2024	First issue
02	14/02/2024	Updated report including pipework and ASHP check

Quality Assurance

[redacted]

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Graduate Engineer

[redacted]

Approved by Jonathan Hays

Director

Contents

1.0 Executive Summary

CK21 have been appointed by Equans to carry out a structural appraisal of the proposal to install PV panels on the roof of a university building.

This report is related to the roof at Coach Lane Library, Northumbria University (blocks F,G and H) only. Any similar properties would need to be inspected individually to determine their viability.

This assessment shows that the duo-pitched roofs have sufficient capacity to support a fixed PV array.

The PV arrays should be placed 2.64m from the edge of the roof, and a minimum of 8no. support clips should be used per panel to fix the PV units to the standing seam roof.

The requirements of Part 14, Class J the 'Town and Country Planning (General Permitted Development) (England) Order 2015' should also be noted:

Development is not permitted by Class J if—

(a)the solar PV equipment or solar thermal equipment would be installed on a pitched roof and would protrude more than 0.2 metres beyond the plane of the roof slope when measured from the perpendicular with the external surface of the roof slope;

(b)the solar PV equipment or solar thermal equipment would be installed on a flat roof, where the highest part of the solar PV equipment would be higher than 1 metre above the highest part of the roof (excluding any chimney);

(c)the solar PV equipment or solar thermal equipment would be installed within 1 metre of the external edge of that roof;

2.0 Brief

CK21 have been appointed by Equans to complete a roof loading assessment of the Coach Lane Library. The purpose of the load assessment is to determine if the roof structure of the property has the capacity to support a PV array.

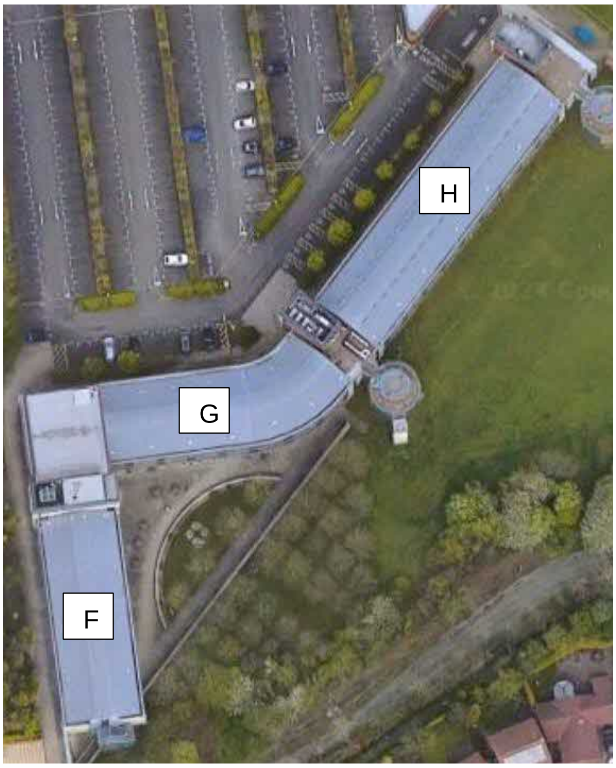


Figure 1 - Satellite view of the existing roof of the property, extract from Google Maps.

The building in question is split into 3 blocks, F,G and H with F being located at the bottom left, G block in the middle of the two and H being the top right. The building is a braced steel-frame structure with a duo-pitched roof.

3.0 Existing Property Description

The roof appears to be made up of concrete slabs that span the roof with a services corridor that runs down the ridge of the roof. The service corridor forms the duo-pitched roof that sits on top of the concrete slabs. Access to the roof level is gained by an external staircase at the side of the building with the roofs construction and build up being visible from the service corridor.

Figure 2 - Hipped roof, photo by CK21.

The service corridor consists of block work walls with access hatches into the roof voids on either side of the corridor where the plant is located. The roof has an approximate pitch of 17° and an apex height of 13.2m, consisting of 260mm x 105mm UB at 2.7m c/c and 80mm x 80mm SHS columns shown in figures 3 and 4.

The rafters of the roof were made up of 190mm x 50mm timber sections at 600mm c/c. While access to rafters was limited, it could be seen that the rafters run down the slope of the pitched roof with a timber decking over them. The standing seam sheeting appears to be fixed to the timber decking, but more detail is required on the fixing arrangement to confirm this.

The roof build-up and construction is consistent throughout the 3 different blocks. The proposed PV panels are to be located on the areas of roof highlighted in figure 7, with the approximate area being 590m^2.

Figure 3 - 260x150mm UB Sections, photo by CK21.

Figure 4 - Roof's build-up, photo by CK21.

Figure 5 - Roof layout, photo by CK21.

Figure 6 - Timber rafters, photo by CK21.

4.0 Proposed PV Array

A PV array layout has been provided by Equans, shown below.

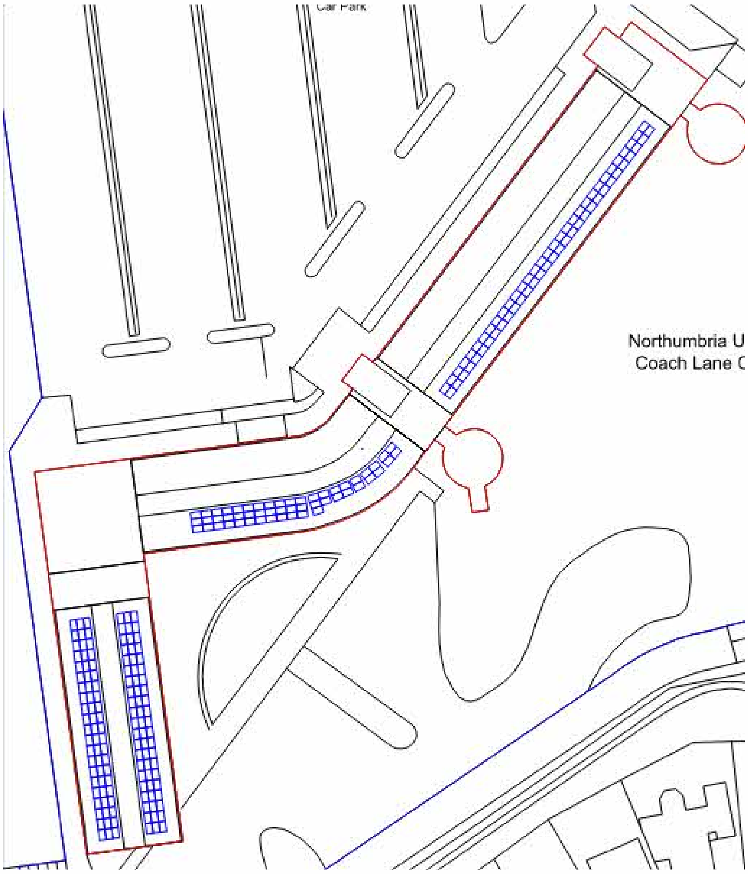


Figure 7 - Proposed PV array arrangement by Equans.

We have based our calculations on the assumption that the PV array will be clipped/fixed to the timber decking, the gap between the underside of the PV panels and the top of the roof deck is not to exceed 200mm. The client intends to use the JAM54S30 JA Solar panels, with the technical information as follows:

- Weight = 19.5kg (~ 0.2kN)
- Area = (1.722x1.134m=) 1.95m^2
- Area Load (kN/m^2) = (0.2 / (1.722x1.134m)) = 0.10kN/m^2

Use an area load of 0.15kN/m^2 for a fixed array including fixing infrastructure.

5.0 Assessment

To evaluate the structural capacity of the roofs, 3 separate roof assessments were completed. The worst-case scenario when considering the wind load and pressure on the roofs was used which was H block, with the remaining 2 assessments shown in appendix 2 and 3.

5.1 H Block

5.1.1 Existing Roof Design Loads

Imposed

0.6 kN/m^2 is assumed where no access is provided to the roof (other than for cleaning or maintenance) unless the snow load exceeds this. The snow load of 0.41kN/m^2 does not exceed the 0.6 kN/m^2 threshold.

Dead	kN/m^2
Insulation	0.10
Roof Sheeting/Cladding	0.10
Rafters and board	0.20
Total	0.40

Wind Load

The wind load for the uplift and positive pressure in the central and edge zones can be seen below:

Edge distance, e = 2.64m

Central wind pressure = -0.66 kN/m^2 / 0.42 kN/m^2

Edge wind pressure = -1.49 kN/m^2 / 0.42 kN/m^2

5.1.2 PV loading

Imposed

Where the PV panels are present, it is not possible to walk on the roof, therefore take the imposed load as the snow load of 0.41kN/m^2.

Dead	kN/m^2
Insulation	0.10
Roof Sheeting/Cladding	0.10
Rafters and board	0.20
PV Panels	0.15
Total	0.55

Wind Load

The wind load applied to the roof is unchanged by the PV panels, so is as existing:

Edge distance, e = 2.64m

Central wind pressure = -0.66 kN/m^2 / 0.42 kN/m^2

Edge wind pressure = -1.49 kN/m^2 / 0.42 kN/m^2

5.1.3 Load Combinations

The table below shows the data regarding the strength and uplift load combinations with the worst-case values.

Load Combination	Main Structure		
	Original Design Load (kN/m^2)	Proposed Design Load (kN/m^2)	% Increase
1.35G +1.5Q	1.44	1.36	-5.8%
1.35G+1.5Q +1.5$\psi W_{downward}$ (CENTRAL)	1.75	1.67	-4.8%
1.0G+1.5W_{uplift} (CENTRAL)	-0.58	-0.43	No net uplift
1.35G+1.5Q +1.5$\psi W_{downward}$ (EDGE)	1.75	1.67	-4.8%
1.0G+1.5W_{uplift} (EDGE)	-1.84	-1.69	No net uplift
1.35G+1.5ψQ +1.5$W_{downward}$ (CENTRAL)	1.79	1.80	≈0
1.35G+1.5ψQ +1.5$W_{downward}$ (EDGE)	1.79	1.80	≈0

The net increase does not exceed 15% for any of the load combinations, the roof has sufficient capacity to support the PV arrays.

6.0 Fixings

Equans intends to use Standing Seam Flat from Sunfixings. Limited information was provided on the Standing Seam Flat fixings; therefore, a max point load capacity of 0.9kN was taken for a conservative approach.

The exact fixing details on the roof decking and Standing Seam sheets is unknow, therefore it is recommended that the number of clips used for the PV panel fixing is increased from 4 to 8 clips. The clips should be spaced equally across all PV panels. See extract below for the proposed changes.

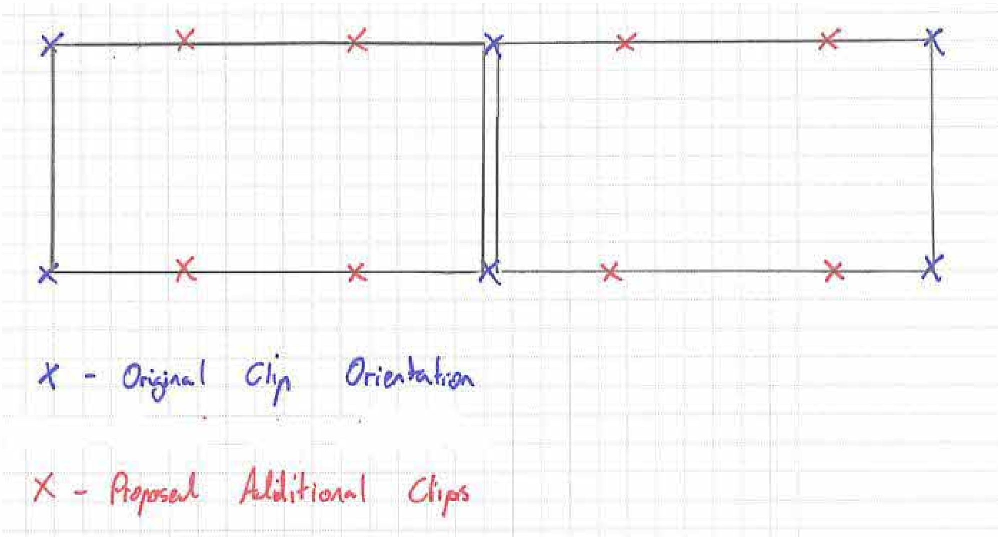


Figure 8 – Proposed clip orientation.

The maximum load per fixing of the PV panels = 0.28kN (uplfit) < 0.9kN (Min. point load that the roof sheeting should have been designed for) which means that the panel fixings are suitable.

The proposed plans show that most of the panels are between 2m and 2.5m of the edges shown in the extract below, it is advised that these panels should not be within 2.64m of the roof edges and that the proposed plans are revised for this detail.

The arrangement of the fixings should ensure that the gap between the PV panel and the existing roof surface does not exceed 200mm.

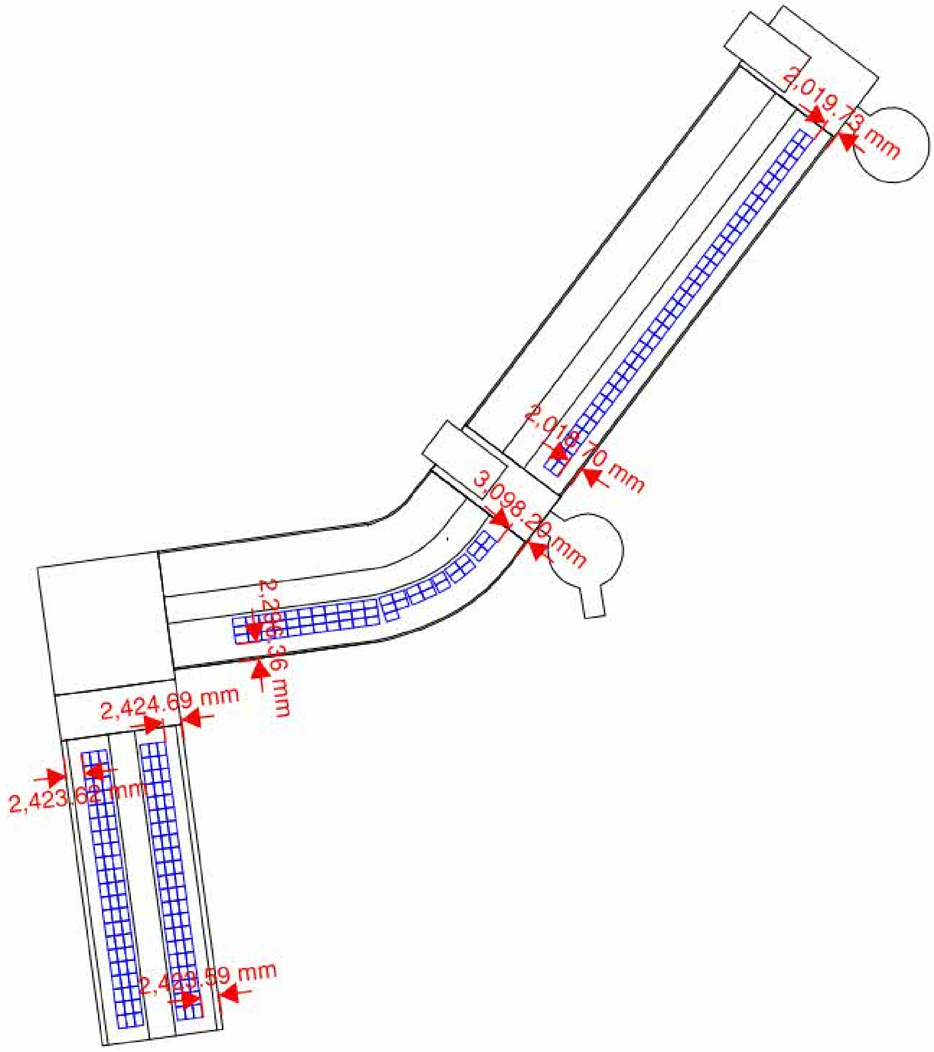


Figure 9 - Proposed PV panel orientation.

7.0 Pipework Check

Equans plan to install 2 pipes that will run on either side of the lighting in the plant corridor, see extract bellow. The total length of the pipes will be approximately 110m, running through H and G block.

The pipes are divided into lengths, with 1 length being 6.4m. The tube diameter is 101.6mm with 2 flanges. The weight of the tubes is 91kg per length.

Figure 10 : Service corridor, photo by CK21.

91kg per length   0.9 kN per length

0.9 / 6.4 = 0.14 kN/m

Area of the pipe:

D = 0.1016m   R = 0.0508m

$\pi \times 0.0508^2 = 0.008m^2$

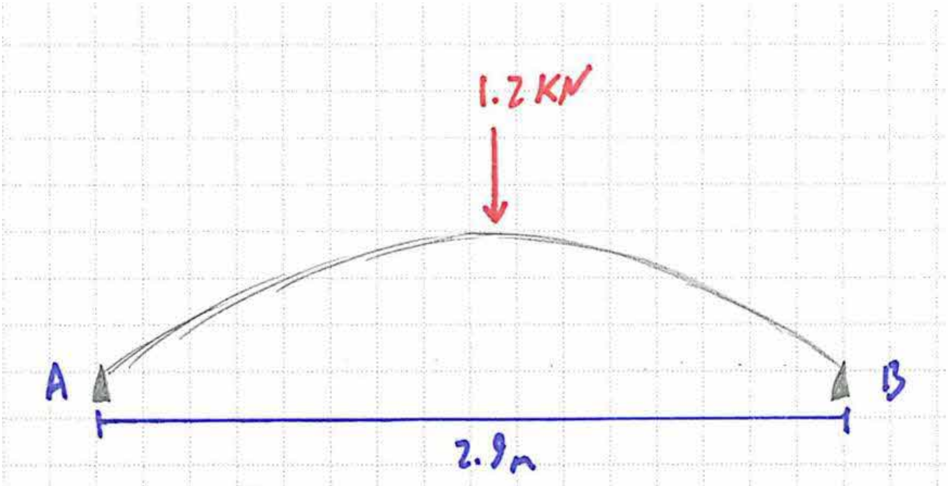
Volume of water = 1000 kg/m^3 10 kN/m^3

0.008 x 10 = 0.08 kN/m

0.08 + 0.14 = 0.22 kN/m

0.22 x 2.7 = 0.6 kN

0.6 x 2 = 1.2 kN Point load from both pipes



Max moments at the point load:

(1.2 x 2.9) / 4 = 0.87 kNm

Moment's capacity taken from the 'Blue Book' = 85.5 kNm (254 x 146 UB 31, Le = 3.0m)

0.87 kNm equates to 1.02% of the moments capacity, as of a result we are confident that the beams will be able to support the additional load coming from the pipes.

8.0 ASHP Checks

8.1 H Block

Equans plan to install 3 air source heat pumps next to H block. There will be 2 different ASHP, an ASPEN 150/160 and two ASPEN 280/211 with both sitting on a 12m x 8m concrete pad.

ASPEN 150/160:

2.22m x 4.381m

3076 kg 30.17 kN

ASPEN 280/211:

2.22m x 5.493m

4671 kg 45.81 kN

12m x 8m = 96m^2

30.17 + 45.81 + 45.81 = 121.79 kN

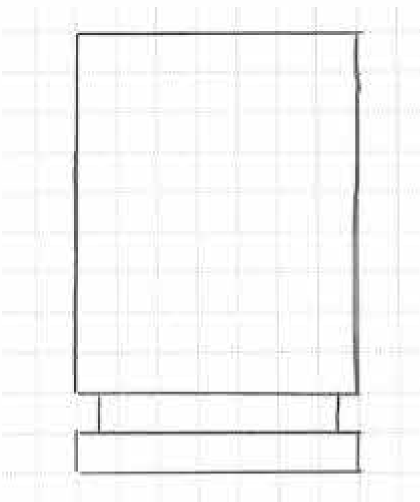
Bearing Pressure = 121.79 / 96 = 1.27 kN/m^2

Self-weight of slab = 24 x 0.2 = 4.8 kN/m^2

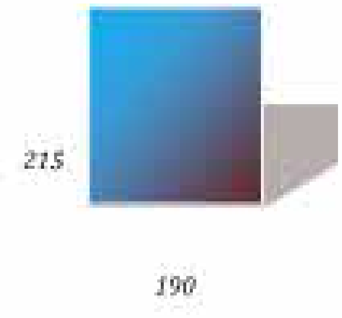
Total Bearing pressure = 1.27 + 4.8 = 6.07 kN/m^2 Acceptable

8.2 Sports Hall

3 ASPEN 150/160 air source heat pumps are planned to be installed next to the sports hall. Each pump will be on big feet supports at each corner with the feet sitting on 2 concrete slabs/lintels. Extract below shows the proposed plan.



The exact build-up of the tarmac area where the concrete slabs/lintels will sit on is unknown, the construction of the proposed area was likely designed to accommodate maintenance vehicles. Currently on the proposed area where the pumps are set to be placed sit 3 heavy containers therefore it can be assumed that the build-up will be able to accommodate the heat pumps.



Declared performance

R190	Lintel Length											
Essential Characteristics	*900*	*1100*	*1200*	*1350*	*1500*	*1800*	*2100*	*2400*	*2700*	*3000*	*3300*	*3600*
Load bearing capacity (kNm-1)	126.49	101.00	91.72	87.87	70.66	46.87	33.22	24.68	18.98	14.99	12.08	10.56
Deflection at 1/3 of load capacity(mm)	0.82											
Thermal Resistance	Thermal conductivity $\lambda_{10,dry,mat}$ (according to EN 1745) 1.52 W/m.K											
Resistance to Fire	R30											
Durability of Performance characteristics against corrosion	C2 - from table C3 EN 845-2:2013 (E)											
Durability of performance characteristics against freeze/thaw cycle	Resistant											
Dangerous Substances	None											

Figure 11 - Concrete slab/lintel specification.

ASPEN 150/160:

2.22m x 4.381m

3076 kg 30.17 kN

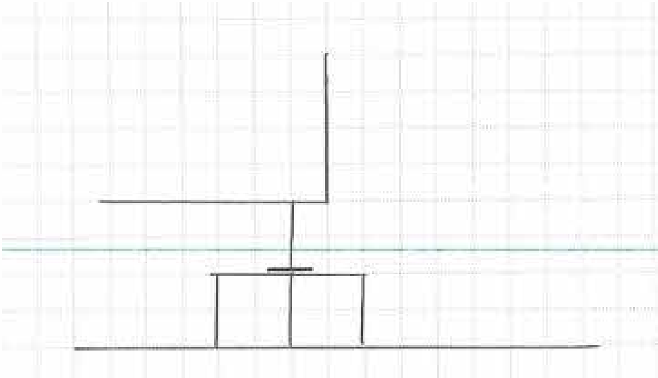
30.17 / 2 = 15.1 kN (each slab/lintel will support 2 big feet supports)

0.19m x 2.3m = 0.42m^2

15.1 kN / 0.42m^2 = 35.95 kN/m^2

It is advised that 2 slabs/lintels are used underneath each big feet support add more support and a better platform for the heat pumps. Shown in the extract below.

35.9kN/m^2 / 2 = 18 kN/m^2 < 24.68 kN/m^2 Acceptable



9.0 Conclusion

This assessment shows that the Coach Lane Library has sufficient capacity to support the fixed PV arrays.

The PV arrays should be placed 2.64m from the edge of the roof.

It is recommended that the number of clips used for the PV panel fixing is increased from 4 to 8 clips.

The air source heat pumps at the sports hall should sit over 2 slab/lintel to ensure stability of the platform.

The requirements of Part 14, Class J the 'Town and Country Planning (General Permitted Development) (England) Order 2015' should also be noted:

Development is not permitted by Class J if—

(a)the solar PV equipment or solar thermal equipment would be installed on a pitched roof and would protrude more than 0.2 metres beyond the plane of the roof slope when measured from the perpendicular with the external surface of the roof slope;

(b)the solar PV equipment or solar thermal equipment would be installed on a flat roof, where the highest part of the solar PV equipment would be higher than 1 metre above the highest part of the roof (excluding any chimney);

(c)the solar PV equipment or solar thermal equipment would be installed within 1 metre of the external edge of that roof;

10.0 Appendices

Appendix 1 – Snow Loading

Calculations following IStructE 'Manual for the Design of Building Structures to Eurocodes 1 & Basis of Structural Design.'

F Block:

Snow Load on the Ground, (S_k):

s_k = (0.15 + (0.1Z + 0.05)) + ((A – 100) / 525) (Eq 5.1)

Z = 4, A = 56m (Fig 5.1)

s_k = (0.15 + (0.1(4) + 0.05)) + ((56 – 100) / 525)

s_k = 0.516 kN/m^2

Snow Load on the Roof, (S):

s = μ_1 x C_e x C_t x s_k (Eq 5.2)

C_e = C_t = 1.0

μ_1 = Roof pitch 17° -> μ_1 = 0.8 (Table 5.1)

s = 0.8 x 1.0 x 1.0 x 0.516

s = 0.41 kN/m^2

G Block:

Snow Load on the Ground, (S_k):

s_k = (0.15 + (0.1Z + 0.05)) + ((A – 100) / 525) (Eq 5.1)

Z = 4, A = 56m (Fig 5.1)

s_k = (0.15 + (0.1(4) + 0.05)) + ((56 – 100) / 525)

s_k = 0.516 kN/m^2

Snow Load on the Roof, (S):

s = μ_1 x C_e x C_t x s_k (Eq 5.2)

C_e = C_t = 1.0

μ_1 = Roof pitch 17° -> μ_1 = 0.8 (Table 5.1)

s = 0.8 x 1.0 x 1.0 x 0.516

s = 0.41 kN/m^2

Calculation Sheet

H Block:

Snow Load on the Ground, (S_k):

$s_k = (0.15 + (0.1Z + 0.05)) + ((A – 100) / 525)$ (Eq 5.1)

$Z = 4, \quad A = 56m$ (Fig 5.1)

$s_k = (0.15 + (0.1(4) + 0.05)) + ((56 – 100) / 525)$

$s_k = 0.516 \text{ kN/m}^2$

Snow Load on the Roof, (S):

$s = \mu_1 \times C_e \times C_t \times s_k$ (Eq 5.2)

$C_e = C_t = 1.0$

μ_1 = Roof pitch 17° -> $\mu_1 = 0.8$ (Table 5.1)

$s = 0.8 \times 1.0 \times 1.0 \times 0.516$

$s = 0.41 \text{ kN/m}^2$

Appendix 2 – Existing Wind Loads

Calculations following IStructE 'Manual for the Design of Building Structures to Eurocodes 1 & Basis of Structural Design.

Basic Wind Velocity, (V_b):

V_b = C_{dir} X C_{season} X C_{prob} X $V_{b,o}$

$V_{b,o}$ = V_{bmap} X C_{alt}

V_{bmap} = 24 m/s

C_{alt} = 1 + 0.001 A
= 1 + 0.001 (56)
= 1.056

$V_{b,o}$ = 24 x 1.056 = 25.34 m/s

C_{season} = C_{prob} = 1.0

V_b = C_{dir} X C_{season} X C_{prob} X $V_{b,o}$

For values of c_{dir} and v_b see tables below.

Basic Velocity Pressure, (q_b):

q_b = 0.613 x $v_b{}^2$

For values of q_b see table below.

Peak Velocity Pressure, ($q_{p\,(z)}$):

$q_{p(z)}$ = $C_{e(z)}$ X q_b X $C_{e,T}$

<u>F Block:</u>

Building Height (z) = 13.2m

e/10 = b / 10 or 2H / 10 (Whichever is smaller)

e/10 = 40/10 or 2(13.2)/10

e = 2.64m

<u>G Block:</u>

Building Height (z) = 13.2m

e/10 = b / 10 or 2H / 10 (Whichever is smaller)

e/10 = 44/10 or 2(13.2)/10

e = 2.64m

Calculation Sheet

Project				Project No.
Coach Lane, Northumbria University				23160
Completed by	Checked by	Sheet No.	Ref	Date
JA		4		23/01/2024

Calculation Details

H Block:

Building Height (z) = 13.2m

e/10 = b / 10 or 2H / 10 (Whichever is smaller)

e/10 = 59/10 or 2(13.2)/10

e = 2.64m

F Block:

	8º (wind on side)	98º (wind on gable)	188º (wind on side)	278 º (wind on gable)
Distance from shoreline (km)	10	<100	100	69
Distance from country terrain (km)	0.2	8.3	9.6	5
c_{dir}	0.78	0.74	0.85	0.99
c_{alt}	1.056	1.056	1.056	1.056
$v_{b,o}$ (m/s)	25.34	25.34	25.34	25.34
v_b (m/s)	19.77	18.75	21.54	25.09
q_b (N/m^2)	239.60	215.51	284.41	385.89
$c_{e(z)}$	2.7	2.5	2.5	2.4
$c_{e(t)}$	1.0	0.82	0.82	0.84
$q_{p(z)}$ (kN/m^2)	0.65	0.44	0.58	0.78
Internal coefficient	0.2/-0.3	0.2/-0.3	0.2/-0.3	0.2/-0.3
Internal pressure (kN/m^2)	0.13/-0.195	0.088/-0.132	0.116/-0.174	0.156/-0.234
F coefficient	-1.0/0.2	-1.6/0.2	-1.0/0.2	-1.6/0.2
Pressure, F Zone (kN/m^2)	-0.65/**0.13**	**-0.704**/0.088	-0.58/0.116	-
G coefficient	-0.7/0.2	-1.4/0.2	-0.7/0.2	-1.4/0.2
Pressure, G Zone (kN/m^2)	-0.455/0.13	-0.62/0.099	-0.406/0.116	-
H coefficient	-0.4/0.2	-0.6/0.2	-0.4/0.2	-0.6/0.2
Pressure, H Zone (kN/m^2)	-0.26/**0.13**	-0.264/0.088	-0.232/0.116	-
I coefficient	-0.5/-0.5	-0.4/0.2	-0.5/-0.5	-0.4/0.2
Pressure, I Zone (kN/m^2)	**-0.325**	-0.176/0.088	-0.29	-

Internal Pressure:

$q_{p(z)}$ x internal coefficient

External Pressure:

$q_{p(z)}$ x external coefficient

Maximum Pressure :

Edge downward pressure= 0.13 – (-0.195) = 0.325 kN/m^2

Edge uplift pressure= -0.704 – (0.088) = -0.792 kN/m^2

Central uplift pressure= -0.325 - (0.13) = -0.455 kN/m^2

Central downward pressure= 0.13 - (-0.195) = 0.325 kN/m^2

G Block:

	26º (wind on gable)	**116º (wind on side)**	**206º (wind on gable)**	**296 º (wind on side)**
Distance from shoreline (km)	9.50	<100	<100	74
Distance from country terrain (km)	0.65	8.11	10.30	4.42
c_{dir}	0.73	0.73	0.93	0.91
c_{alt}	1.056	1.056	1.056	1.056
$v_{b,o}$ (m/s)	25.34	25.34	25.34	25.34
v_b (m/s)	18.50	18.50	23.57	23.06
q_b (N/m^2)	209.80	209.80	340.55	325.97
$c_{e(z)}$	2.7	2.6	2.6	2.6
$c_{e(t)}$	0.98	0.82	0.82	0.86
$q_{p(z)}$ (kN/m^2)	0.56	0.45	0.73	0.73
Internal coefficient	0.2/-0.3	0.2/-0.3	0.2/-0.3	0.2/-0.3
Internal pressure (kN/m^2)	0.112/-0.168	0.09/-0.135	0.146/-0.219	0.146/-0.219
F coefficient	-1.6/0.2	-1.0/0.2	-1.6/0.2	-1.0/0.2
Pressure, F Zone (kN/m^2)	-0.895/0.112	-0.45/0.09	**-1.168/0.146**	-0.73/0.146
G coefficient	-1.4/0.2	-0.7/0.2	-1.4/0.2	-0.7/0.2
Pressure, G Zone (kN/m^2)	-0.784/0.112	-0.315/0.09	-1.022/0.146	-0.511/0.146
H coefficient	-0.6/0.2	-0.4/0.2	-0.6/0.2	-0.4/0.2
Pressure, H Zone (kN/m^2)	-0.336/0.112	-0.18/0.09	**-0.438/0.146**	-0.292/0.146
I coefficient	-0.4/0.2	-0.5/-0.5	-0.4/0.2	-0.5/-0.5
Pressure, I Zone (kN/m^2)	-0.224/0.112	-0.225	-0.292/0.146	-0.365

Internal Pressure:

$q_{p(z)}$ x internal coefficient

External Pressure:

$q_{p(z)}$ x external coefficient

Maximum Pressure :

Edge downward pressure= 0.146 – (-0.219) = 0.365 kN/m^2

Edge uplift pressure= -1.168 – (0.146) = -1.314 kN/m^2

Central uplift pressure= -0.438 – (0.146) = -0.584 kN/m^2

Central downward pressure= 0.146 – (-0.219) = 0.365 kN/m^2

H Block:

	52º (wind on gable)	142º (wind on side)	232º (wind on gable)	322 º (wind on side)
Distance from shoreline (km)	11	16	<100	<100
Distance from country terrain (km)	≈ 0	≈ 0	8	2
c_{dir}	0.73	0.80	1.00	0.82
c_{alt}	1.056	1.056	1.056	1.056
$v_{b,o}$ (m/s)	25.34	25.34	25.34	25.34
v_b (m/s)	18.50	20.27	25.34	20.78
q_b (N/m^2)	209.80	251.86	393.61	264.70
$c_{e(z)}$	2.6	2.6	2.5	2.5
$c_{e(t)}$	1.0	1.0	0.84	0.90
$q_{p(z)}$ (kN/m^2)	0.55	0.65	0.83	0.60
Internal coefficient	0.2/-0.3	0.2/-0.3	0.2/-0.3	0.2/-0.3
Internal pressure (kN/m^2)	0.11/-0.165	0.13/-0.195	0.166/-0.249	0.12/-0.18
F coefficient	-1.6/0.2	-1.0/0.2	-1.6/0.2	-1.0/0.2
Pressure, F Zone (kN/m^2)	-0.88/0.11	-0.65/0.13	**-1.328/0.166**	-0.6/0.12
G coefficient	-1.4/0.2	-0.7/0.2	-1.4/0.2	-0.7/0.2
Pressure, G Zone (kN/m^2)	-0.77/0.11	-0.455/0.13	-1.162/0.166	-0.42/0.12
H coefficient	-0.6/0.2	-0.4/0.2	-0.6/0.2	-0.4/0.2
Pressure, H Zone (kN/m^2)	-0.33/0.11	-0.26/0.13	**-0.498/0.166**	-0.24/0.12
I coefficient	-0.4/0.2	-0.5/-0.5	-0.4/0.2	-0.5/-0.5
Pressure, I Zone (kN/m^2)	-0.22/0.11	-0.325	-0.332/0.166	-0.3

Internal Pressure:

$q_{p(z)}$ x internal coefficient

External Pressure:

$q_{p(z)}$ x external coefficient

Maximum Pressure :

Edge downward pressure = 0.166 – (-0.249) = 0.415 kN/m^2

Edge uplift pressure = -1.328 – (0.166) = -1.494 kN/m^2

Central uplift pressure = -0.489 – (0.166) = -0.655 kN/m^2

Central downward pressure = 0.166 – (-0.249) = 0.415 kN/m^2

Appendix 3 – Load Combinations

Calculation Sheet

Project	Project No.
Coach Lane, Northumbria University	23160

Completed by	Checked by	Sheet No.	Ref	Date
JA		8		23/01/2024

Calculation Details

Load Combination:

F Block:

Load Combination	Original Design Load (kN/m^2)	Proposed Load (kN/m^2)	% Increase
1.35G +1.5Q	1.35 x 0.4 + 1.5 x 0.6 = **1.44**	1.35 x 0.55 + 1.5 x 0.41 = **1.36**	**-5.8%**
1.35G+1.5Q +1.5ψ$W_{downward}$ (CENTRAL)	1.35 x 0.4 + 1.5 x 0.6 + 1.5 x 0.5 x 0.325 = **1.68**	1.35 x 0.55 + 1.5 x 0.41 + 1.5 x 0.5 x 0.325 = **1.60**	**-5%**
1.0G+1.5W_{uplift} (CENTRAL)	1 x 0.4 + 1.5 x -0.455 = **-0.28**	1 x 0.55 + 1.5 x -0.455 = **-0.13**	**No net uplift**
1.35G+1.5Q +1.5ψ$W_{downward}$ (EDGE)	1.35 x 0.4 + 1.5 x 0.6 + 1.5 x 0.5 x 0.325 = **1.68**	1.35 x 0.55 + 1.5 x 0.41 + 1.5 x 0.5 x 0.325 = **1.60**	**-5%**
1.0G+1.5W_{uplift} (EDGE)	1 x 0.4 + 1.5 x -0.792 = **-0.79**	1 x 0.55 + 1.5 x -0.792 = **-0.64**	**No net uplift**
1.35G+1.5ψQ +1.5$W_{downward}$ (CENTRAL)	1.35 x 0.4 + 1.5 x 0.7 x 0.6 + 1.5 x 0.325 = **1.66**	1.35 x 0.55 + 1.5 x 0.7 x 0.41 + 1.5 x 0.325 = **1.66**	≈**0**
1.35G+1.5ψQ +1.5$W_{downward}$ (EDGE)	1.35 x 0.4 + 1.5 x 0.7 x 0.6 + 1.5 x 0.325 = **1.66**	1.35 x 0.55 + 1.5 x 0.7 x 0.41 + 1.5 x 0.325 = **1.66**	≈**0**

Dead Load	kN/m^2
Insulation	0.10
Roof Sheeting/Cladding	0.10
Rafters and board	0.20
Total	0.40

Dead Load (PV Panels)	kN/m^2
Insulation	0.10
Roof Sheeting/Cladding	0.10
Rafters and board	0.20
PV Panels	0.15
Total	0.55

G Block:

Load Combination	Original Design Load (kN/m^2)	Proposed Load (kN/m^2)	% Increase
1.35G +1.5Q	1.35 x 0.4 + 1.5 x 0.6 = **1.44**	1.35 x 0.55 + 1.5 x 0.41 = **1.36**	**-5.8%**
1.35G+1.5Q +1.5ψ$W_{downward}$ (CENTRAL)	1.35 x 0.4 + 1.5 x 0.6 + 1.5 x 0.5 x 0.365 = **1.71**	1.35 x 0.55 + 1.5 x 0.41 + 1.5 x 0.5 x 0.365 = **1.63**	**-5%**
1.0G+1.5W_{uplift} (CENTRAL)	1 x 0.4 + 1.5 x -0.584 = **-0.48**	1 x 0.55 + 1.5 x -0.584 = **-0.33**	**No Net Uplift**
1.35G+1.5Q +1.5ψ$W_{downward}$ (EDGE)	1.35 x 0.4 + 1.5 x 0.6 + 1.5 x 0.5 x 0.365 = **1.71**	1.35 x 0.55 + 1.5 x 0.41 + 1.5 x 0.5 x 0.365 = **1.63**	**-5%**
1.0G+1.5W_{uplift} (EDGE)	1 x 0.4 + 1.5 x -1.314 = **-1.57**	1 x 0.55 + 1.5 x -1.314 = **-1.42**	**No Net Uplift**
1.35G+1.5ψQ +1.5$W_{downward}$ (CENTRAL)	1.35 x 0.4 + 1.5 x 0.7 x 0.6 + 1.5 x 0.365 = **1.72**	1.35 x 0.55 + 1.5 x 0.7 x 0.41 + 1.5 x 0.365 = **1.72**	≈**0**
1.35G+1.5ψQ +1.5$W_{downward}$ (EDGE)	1.35 x 0.4 + 1.5 x 0.7 x 0.6 + 1.5 x 0.365 = **1.72**	1.35 x 0.55 + 1.5 x 0.7 x 0.41 + 1.5 x 0.365 = **1.72**	≈**0**

Dead Load	kN/m^2
Insulation	0.10
Roof Sheeting/Cladding	0.10
Rafters and board	0.20
Total	0.40

Dead Load (PV Panels)	kN/m^2
Insulation	0.10
Roof Sheeting/Cladding	0.10
Rafters and board	0.20
PV Panels	0.15
Total	0.55

H Block:

Load Combination	Original Design Load (kN/m^2)	Proposed Load (kN/m^2)	% Increase
1.35G +1.5Q	1.35 x 0.4 + 1.5 x 0.6 = **1.44**	1.35 x 0.55 + 1.5 x 0.41 = **1.36**	**-5.8%**
1.35G+1.5Q +1.5ψ$W_{downward}$ (CENTRAL)	1.35 x 0.4 + 1.5 x 0.6 + 1.5 x 0.5 x 0.415 = **1.75**	1.35 x 0.55 + 1.5 x 0.41 + 1.5 x 0.5 x 0.415 = **1.67**	**-4.8%**
1.0G+1.5W_{uplift} (CENTRAL)	1 x 0.4 + 1.5 x -0.655 = **-0.58**	1 x 0.55 + 1.5 x -0.655 = **-0.43**	**No Net Uplift**
1.35G+1.5Q +1.5ψ$W_{downward}$ (EDGE)	1.35 x 0.4 + 1.5 x 0.6 + 1.5 x 0.5 x 0.415 = **1.75**	1.35 x 0.55 + 1.5 x 0.41 + 1.5 x 0.5 x 0.415 = **1.67**	**-4.8%**
1.0G+1.5W_{uplift} (EDGE)	1 x 0.4 + 1.5 x -1.494 = **-1.84**	1 x 0.55 + 1.5 x -1.494 = **-1.69**	**No Net Uplift**
1.35G+1.5ψQ +1.5$W_{downward}$ (CENTRAL)	1.35 x 0.4 + 1.5 x 0.7 x 0.6 + 1.5 x 0.415 = **1.79**	1.35 x 0.55 + 1.5 x 0.7 x 0.41 + 1.5 x 0.415 = **1.80**	≈**0**
1.35G+1.5ψQ +1.5$W_{downward}$ (EDGE)	1.35 x 0.4 + 1.5 x 0.7 x 0.6 + 1.5 x 0.415 = **1.79**	1.35 x 0.55 + 1.5 x 0.7 x 0.41 + 1.5 x 0.415 = **1.80**	≈**0**

Dead Load	kN/m^2
Insulation	0.10
Roof Sheeting/Cladding	0.10
Rafters and board	0.20
Total	0.40

Dead Load (PV Panels)	kN/m^2
Insulation	0.10
Roof Sheeting/Cladding	0.10
Rafters and board	0.20
PV Panels	0.15
Total	0.55

Appendix 4 – Load on the Roof

Calculations following BRE Digest 489 - Wind Loads on Roof - Mounted PV and solar thermal systems

Wind loads on roof-mounted PV and Solar thermal systems:

$w = q_p \, c_{p,net}$ (Eq. 1)

q_p = 985.5 Pa

Altitude correction factor: 1 + (A-100/100) x 0.2 (see Table 1 Note 3)

1 + ((56-100)/100) x 0.2 = 0.912

q_p = 985.5 x 0.912

q_p = 898.78 Pa

From table 2, Duo-pitched roof:

Central Roof zone, $c_{p,net}$= -0.6/0.2

Edge Roof zone, $c_{p,net}$= -1.6/0.2

Central zone, w_{uplift} = 0.899 x -0.5 = -0.45 kN/m^2

Central zone, $w_{downward}$ = 0.899 x 0.2 x 0.66 = 0.12 kN/m^2

Edge zone, w_{uplift} = 0.899 x -1.4 x 0.5 = -0.63 kN/m^2

Edge zone, $w_{downward}$ = 0.899 x 0.2 x 0.66 = 0.12 kN/m^2

(Note: it is recommended for above-roof arrays of two or more modules that the negative pressure coefficients given in Table 2 be multiplied by a reduction factor of 0.5, subject to a minimum negative pressure coefficient of -0.5 for all zones. The positive pressure coefficients given in Table 2 should be multiplied by a reduction factor of 0.66, subject to a minimum positive pressure coefficient of +0.2 for all zones.)

Eq. 2. $F = w \, A \, \gamma_f$, ignore A and conservatively apply the area load over the whole roof. For roof-mounted solar systems a partial safety factor of 1.35 can be applied. This is the typical partial safety factor for wind of 1.5 multiplied by a consequence class factor (CC1) of 0.9.

Central zone, F_{uplift} = -0.45 x 1.35= -0.61 kN/m^2

Central zone, $F_{downward}$ = 0.12 x 1.35 = 0.16 kN/m^2

Edge zone, F_{uplift} = -0.63 x 1.35 = -0.85 kN/m^2

Edge zone, $F_{downward}$ = 0.12 x 1.35 = 0.16 kN/m^2

Calculation Sheet

Project				Project No.
Coach Lane, Northumbria University				23160
Completed by	**Checked by**	**Sheet No.**	**Ref**	**Date**
JA		12		23/01/2024

Calculation Details

Fixing Array:

The client intends to use Sunfixings Standing Seam Flat fixing for the PV arrays.

PV Panels are to be fixed with a minimum of eight clamps, one at each corner and two at third points along the long edge.

Panel area = 1.722m x 1.134m = 1.95m^2

Load per corner (central zone) uplift = ((1.35 x 0.45) x 1.95) / 6 = 0.19 kN

Load per corner (central zone) downward = ((1.35 x 0.12) x 1.95) / 6 = 0.05 kN

Load per corner (edge zone) uplift = ((1.35 x 0.63) x 1.95) / 6 = 0.28 kN

Load per corner (edge zone) downward = ((1.35 x 0.12) x 1.95) / 6 = 0.05 kN

Therefore, the maximum load per fixing of the PV panels = 0.28kN (uplift) < 0.9kN (min. point load that the roof sheeting should have been designed for) which means that the panel fixings are suitable.